1-1-1961

Excursion Across East-Central Vermont, Barre, to Strafford via Bradford

White, Walter S.

Doll, Charles G.

TRIP A-2

Barre to Strafford via Bradford

TRIP A-2

Barre to Strafford via Bradford. Lithology of the rocks between the Shaw Mountain belt and the Monroe line. Monroe fault, development of cleavages on east side of Strafford arch, and structure of Strafford Village area.

East-central Vermont

Between the Northfield slate at Montpelier and the Monroe fault at Bradford, there are four persistent lithologic belts. If these are numbered from west to east, the first and third belts consist of alternations of calcareous and argillaceous beds, and the second and fourth belts consist of alternations of schist and micaceous quartzite beds. Doll (1951) has named the first belt the Barton River formation(Dwb) and the second the Westmore formation. He (Doll, 1944) also named the fourth belt the Gile Mountain formation(Dg). Another name, the Waits River formation(Dw), has been used for the first and third belts collectively (White and Jahns, 1950) on the assumption that the third belt is primarily a structural repetition of the first.

The rocks of these belts overlie the Shaw Mountain formation(Ss) to the west, and are generally considered to be Silurian and/or Devonian in age. They are bordered on the east by the pre-Silurian Albee(Oal) and Ammonoosuc(Oa) formations. The Albee formation is very similar lithologically to the Moretown formation(Omm), and is very probably correlative. Very broadly, therefore, the four belts referred to above collectively represent a wide belt of younger rocks bounded on either side by older rocks. Cady (1960) has referred to this whole wide belt as a synclinorium because of this general relationship.

The first individual belt (Barton River formation) and at least part of the second (Westmore formation) appear to overlie the older rocks to the west in an orderly continuous ascending sequence. The major problem of the geology of east-central Vermont has to do with the nature of the eastern boundary of the fourth belt (Gile Mountain formation) and with the internal structure and order of superposition within the third and fourth belts.

The eastern boundary of the fourth belt transects the bedding of the older rocks to the east on both a regional and local (STOP 4) scale, and has been called a fault, the Monroe fault. Inasmuch as it is principally the older rocks that are truncated, the relationships could be explained by assuming that the boundary is an uncomformity -- the pre-Silurian uncomformity exposed elsewhere in New England -- or possibly an unconformity modified by faulting, so some have preferred to call this boundary the Monroe "line." If the rocks of the fourth belt (Gile Mountain formation) are younger than the calcareous rocks of the third belt, the Monroe "line" obviously must be a fault. If, however, the internal structure of belts 1 to 4 is grossly synclinal, and the rocks of belt four are older than those of belt three, the Monroe "line" may simply be an unconformity.

The order of superposition in belts 3 and 4 is not easy to determine because the original structure, whether synclinal or otherwise, has been obscured by a late-stage deformation that produced, primarily in belt 3, a group of recumbent folds and a tremendous arch in the cleavage and axial planes of these recumbent folds. This cleavage arch can be traced as a continuous arch or

series of en echelon domes for most of the length of Vermont.

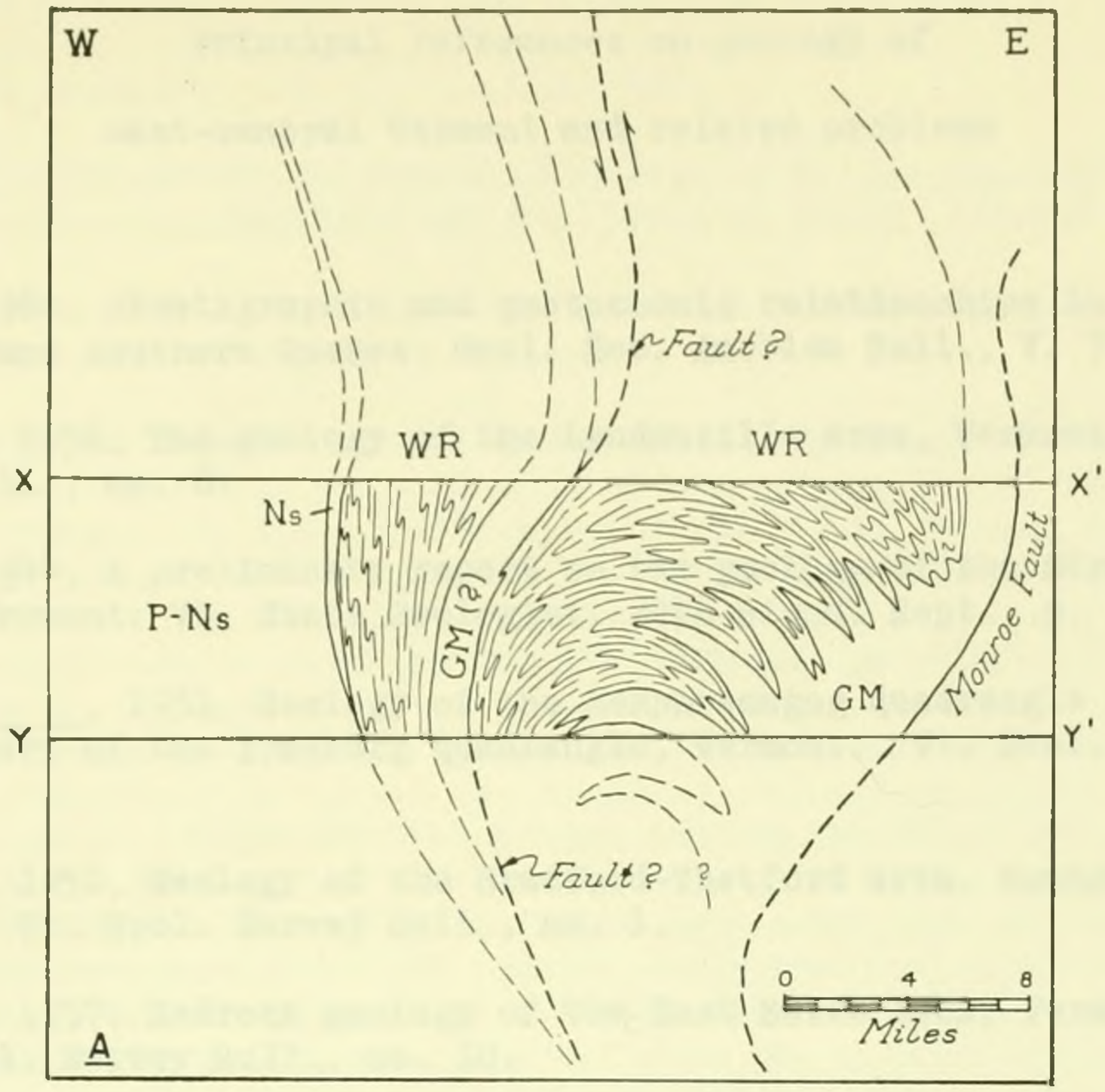
The most likely hypotheses for the structure of belts 1 to 4 are the following:

1) Belt 1 is the same as Belt 3, and Belt 2 is the same as Belt 4. The repetition is due either to coincidence of Belt 2 with a syncline and Belt 3 with an anticline (Dennis, 1956), or to faulting. (Fig. 1A) Correlation of the rocks of belts 2 and 4 is made likely by their apparent connection around the north-plunging nose of the cleavage arch in the Island Pond quadrangle.

2) Belts 2 and 4 are the same, and are connected in depth to form a syncline (Fig. 1B). The rocks of Belt 3 are younger. The rocks of Belt 1 are either older than those of belts 2 and 4, or grade eastward, by change of facies, into those of Belt 4. This hypothesis is difficult to reconcile structurally with the apparent connection of belts 2 and 4 in the Island Pond quadrangle.

3) The sequence is essentially homoclinal from west to east, with Belt 1 the oldest and Belt 4 the youngest. Northward disappearance of the calcareous facies of Belt 3 might explain the apparent junction of belts 2 and 4.

There is, as yet, no certain basis for choice among these hypotheses. The field excursion will be concerned with three main topics: (1) evidence for local truncation along the Monroe fault (or line); (2) evolution of the later-stage structural features (cleavage and minor folds) that obscure the primary structure, and (3), in extension of (2), the recumbent folds with cores of Gile Mountain formation that extend across the cleavage arch in the Strafford village area.



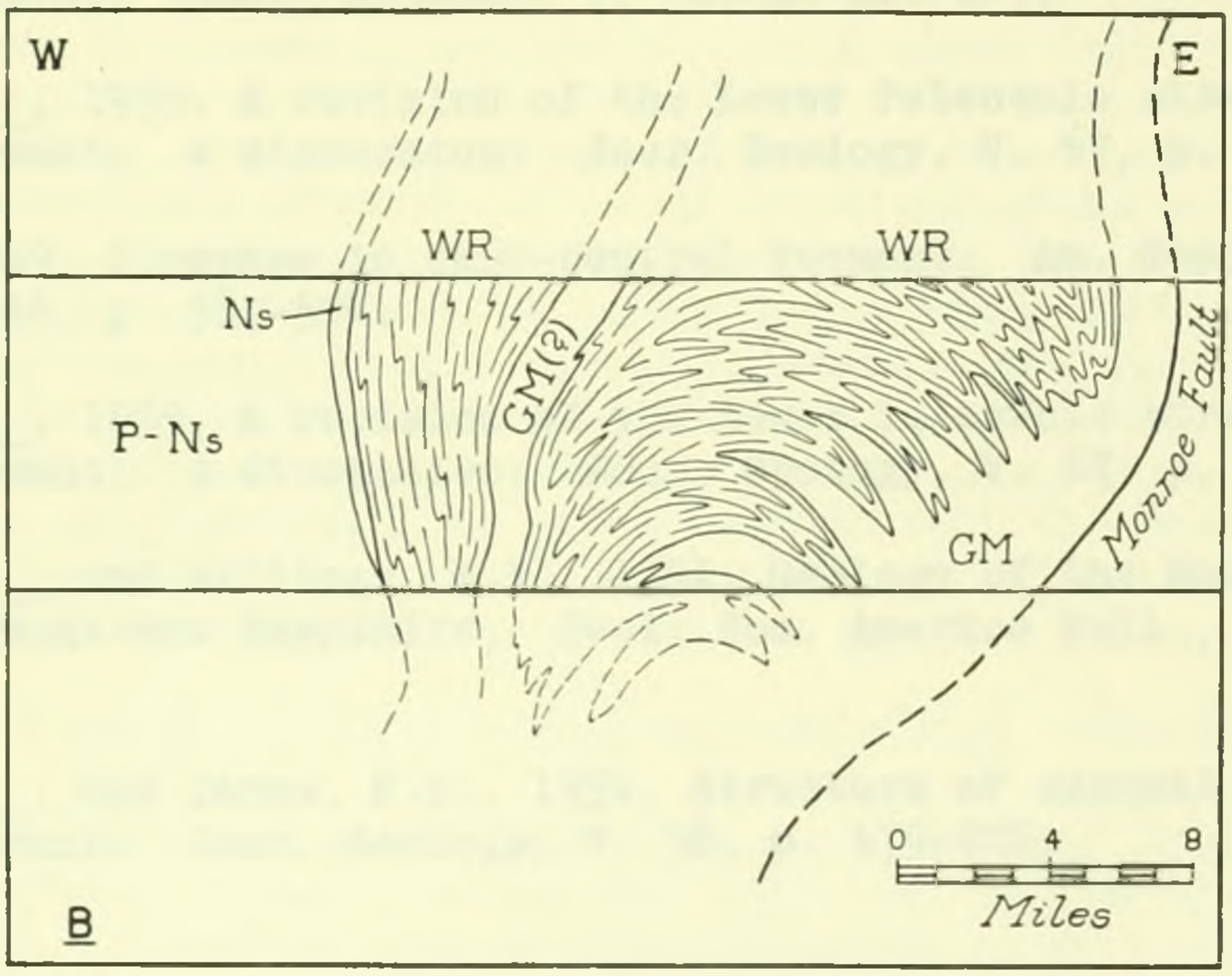


FIG. 12.—(Legend on facing page)

FIG. 12.—Diagrammatic east-west structure sections of central and east-central Vermont, showing two possible interpretations of surface relations. Data projected from map (fig. 2) onto planes of sections, with northward-plunging axes of minor folds as projection lines. Details along lines *X–X′* represent structure exposed in northern part of Barre, East Barre, and Woodsville quadrangles; details along lines *Y–Y′* represent structure at surface at approximate latitude of Bethel and South Strafford. Meetinghouse slate, next to Monroe fault, omitted from diagram. *P–Ns*, rocks older than Northfield slate; *Ns*, Northfield slate; *WR*, Waits River formation; *GM*, Gile Mountain formation; *GM(?)*, rocks provisionally assigned to Gile Mountain formation.

Principal references on geology of

east-central Vermont and related problems

Cady, W.M., 1960, Stratigraphic and geotectonic relationships in northern Vermont, and southern Quebec: Geol. Soc. America Bull., V. 71, p. 531-576.

Dennis, J.G., 1956, The geology of the Lyndonville area, Vermont: Vt. Geol. Survey Bull., no. 8.

Doll, C.G., 1944, A preliminary report on the geology of the Strafford quadrangle, Vermont: Vt. State Geologist, 24th Bienn. Rept., p. 14-28.

_____, 1951, Geology of the Memphremagog quadrangle and the southeastern part of the Irasburg quadrangle, Vermont: Vt. Geol. Survey Bull., no. 3.

Hadley, J.B., 1950, Geology of the Bradford-Thetford area, Orange County, Vermont: Vt. Geol. Survey Bull., no. 1.

Murthy, V.R., 1957, Bedrock geology of the East Barre area, Vermont: Vt. State Geol. Survey Bull., no. 10.

_____, 1958, A revision of the Lower Paleozoic stratigraphy in eastern Vermont: Jour. Geology, V. 66, p. 276-287.

_____, 1959, A revision of the Lower Paleozoic stratigraphy in eastern Vermont: a discussion: Jour. Geology, V. 67, p. 577-581.

White, W.S., 1949, Cleavage in east-central Vermont: Am. Geophys. Union Trans., V. 30, p. 587-594.

_____, 1959, A revision of the Lower Paleozoic stratigraphy in eastern Vermont: a discussion: Jour. Geology, V. 67, p. 577-581.

_____, and Billings, M.P., 1951, Geology of the Woodsville quadrangle, Vermont-New Hampshire: Geol. Soc. America Bull., V. 62, p. 647-696.

_____, and Jahns, R.H., 1950, Structure of central and east-central Vermont: Jour. Geology, V. 58, p. 179-220.

TRIP A-2

Sunday, October 15, 1961, 8:00 A.M. Excursion across east-central Vermont, Barre to Strafford via Bradford.

Leaders: Walter S. White and Charles G. Doll

MILES

0.0 Begin mileage at common in center of Barre, at intersection of Rtes. US 302 and Vt. 14.

Proceed south on Vt. 14 (S. Main St.)

0.9 Turn left, following signs to Websterville.

2.4 Turn left at crossroads by cemetery.

3.7 STOP I - Wells Lamson granite quarry, Websterville

One of the five principal quarries in the Barre "granite", which is primarily used for monumental stone. The rock is an even-grained quartzose granodiorite with biotite as the dark mineral. Differences in color and texture are accentuated by polishing to yield a considerable variety in the finished products.

This pluton is about 4 miles long and 2 miles wide; it intrudes the Westmore formation (= Gile Mountain formation) and the western border of the calcareous Waits River formation. A septum of the Westmore formation almost divides the pluton into two parallel plutons; the margin of this septum can be seen in the east wall of the quarry. Although the contact relations cannot be satisfactorily studied from the quarry rim, it may be remarked that visible contacts are typically parallel to the bedding and a schisosity of the wall rocks, but the cross-cutting relationships are also common. Most contacts are extremely sharp. Both the layering and the long axes of inclusions in the "granite" are more or less randomly oriented. The "granite" post-dates practically all of the deformation of the country rock, and has made way for itself by a combination of stopping and bulging of the country rock.

Bear left at fork just beyond quarry.

4.8 Turn left past stores, and proceed 0.2 miles to highway intersection. Turn right on US 302 (Vt. 25), and follow signs to Bradford. The road for the next 7 miles passes through an area of heavy drift cover, and poor exposure. The hills on the left are underlain by Knox Mtn. granite(nhu).

10.9 Outcrops of Knox Mountain granite on left.

12.1 Bear right on Vt. rte. 25, toward Bradford.

14.1 West Topsham village.

17.8 Waits River village. The rounded grassy tops and very steep lower slopes of the hills here and for the next five miles are typical of the terrain underlain by the Waits River formation. Note the typical dark-brown, rough weathered surface of outcrops of these calcareous rocks.

24.1 Bridge over Waits River. The rocks here and beyond are interbedded schists and micaceous quartzites of the Gile Mountain formation, highly crumpled, for the most part.

25.0 and 25.5 Granite dikes more or less parallel to slip cleavage (later cleavage) in crumpled schists on left.

26.2 to 26.6 STOP II - Bradford Center village

Outcrops of crumpled schist and micaceous quartzite typical of Gile Mountain formation, at both ends of the village. Slip cleavage more or less parallel to the axial planes of the folds is well developed in some parts of the outcrops and poor in others. It tends to be better developed in the schist than in the more quartzose layers. Bedding and an earlier schistosity are crumpled and cut by this slip cleavage. Though the intensity of the later crumpling here tends to obscure the relationship between the earlier schistosity and the bedding, painstaking attempts to follow the trace of individual schistosity surfaces will commonly show that the schistosity and bedding are not strictly parallel. It may, in fact, be difficult to follow individual lithologic boundaries for more than a few feet, which suggests that the rocks were already sheared and folded before being further crumpled and cut by slip cleavage.

A thin granite dike is more or less parallel to the axial plane of the later folds in the outcrop at the southeast end of the village. The dike is later than and unaffected by the folding of the later stage.

28.7 STOP III - Gile Mountain formation with impure carbonate layers.

Rocks are less metamorphosed than those at STOP II. The schistosity and bedding generally strike about N. 20° E., and dip 50-55° S.E. Some tight folds in calcareous layers (best seen on the upper surface of the roadcut) seem to have axial planes parallel to the schistosity, and would thus be classed as folds of the earlier stage (An element of uncertainty exists because the style of folding in the carbonate rocks is commonly different from that in the non-calcareous rocks). Slip cleavage striking about N. 25° W. and dipping 35° N.E. is moderately well developed in some of the more crumpled parts of the exposures, and only incipient in other places.

29.1 At fork in highway, bear right on Route 25A

30.2 Turn right (south) on U.S. Route 5, and proceed 0.3 miles to paved farm road on right.

30.4 STOP IV - Monroe fault at Bradford Lower Plain

Outcrops are 500-1000 feet west of US Rte. 5, and north of the farm road. From east to west, the rocks in this group of outcrops are (1) chlorite schist -- the Sunday Mountain volcanics(Oa) of Hadley, (possibly = Ammonoosuc volcanics); (2) greenish-gray chlorite-sericite schist with thin interbeds of quartzite -- the Albee formation; and (3) dark-gray slaty schist with micaceous quartzite interbeds -- the Meetinghouse member(Dgm) of the Gile Mountain formation. The boundary between (2) and (3) strikes nearly north-south, and is strongly discordant with respect to the northeast-striking schistosity in the rocks on either side; the trend of bedding on both sides is not readily determined, but it, too, seems to be truncated by the boundary.

Some minor folds with sinistral pattern in plan, and northeast-striking slip cleavage parallel to their axial planes, occur locally in the Meetinghouse member. Folds with this pattern and orientation are common in the vicinity of the Monroe fault for 10 miles or so north of here; their orientation and pattern differ notably from those of the later folds formed farther west (e.g. at STOPS II and III).

From STOP IV, retrace route for 1.4 miles.

30.8 At 0.3 miles north of STOP IV, turn left onto Rte. 25A.

31.9 Bear left on Route 25.

32.0 Leave Route 25, and bear left on Rowell Brook Road.

33.2 Go straight at cross roads.

34.2 Go straight at cross roads.

35.1 Bear left on gravel road.

38.3 STOP V - West Fairlee Center, roadcut 0.3 miles northeast of church.

Gile Mountain formation, mainly dark-gray mica schist in this exposure. The slip-cleavage is still clearly recognizable as such in this outcrop, particularly if one examines it with a hand lens: though the cleavage planes are very closely spaced in most of the rock here, the earlier schistosity is still visible in the plates between slip-cleavage surfaces. Farther west the spacing becomes still closer, and it becomes more and more difficult to find remnants of the earlier schistosity that are not smeared into parallelism with the slip-cleavage.

38.6 Church on right.

42.7 Turn right at intersection on north side of Lake Fairlee.

43.2 Bear right, away from lake, at fork.

44.6 Turn right (north) on Rte. 113 at intersection.

45.6 West Fairlee. Turn left at general store.

47.1 Dumps and slag piles of old Ely (Copperfield) copper mine.
The mine, whose main opening is 0.7 mi. north of the road, was last operated in 1905. During the '50's, considerable copper was reclaimed from the dumps by the operators of the Elizabeth mine at Strafford.

47.7 Bear left at fork.

48.6 STOP VI - Gile Mountain formation

Outcrops in pasture on right are predominantly micaceous quartzite, with subordinate mica schist and kyanite mica schist. The schistosity here has the same general attitude as the slip-cleavage at STOP V, and is believed to represent the end-product of intense development of slip-cleavage. The schistosity is parallel to the axial planes of minor folds; these folds are predominantly dextral in pattern, reflecting their position on the southwest flank of a major fold that opens to the southeast.

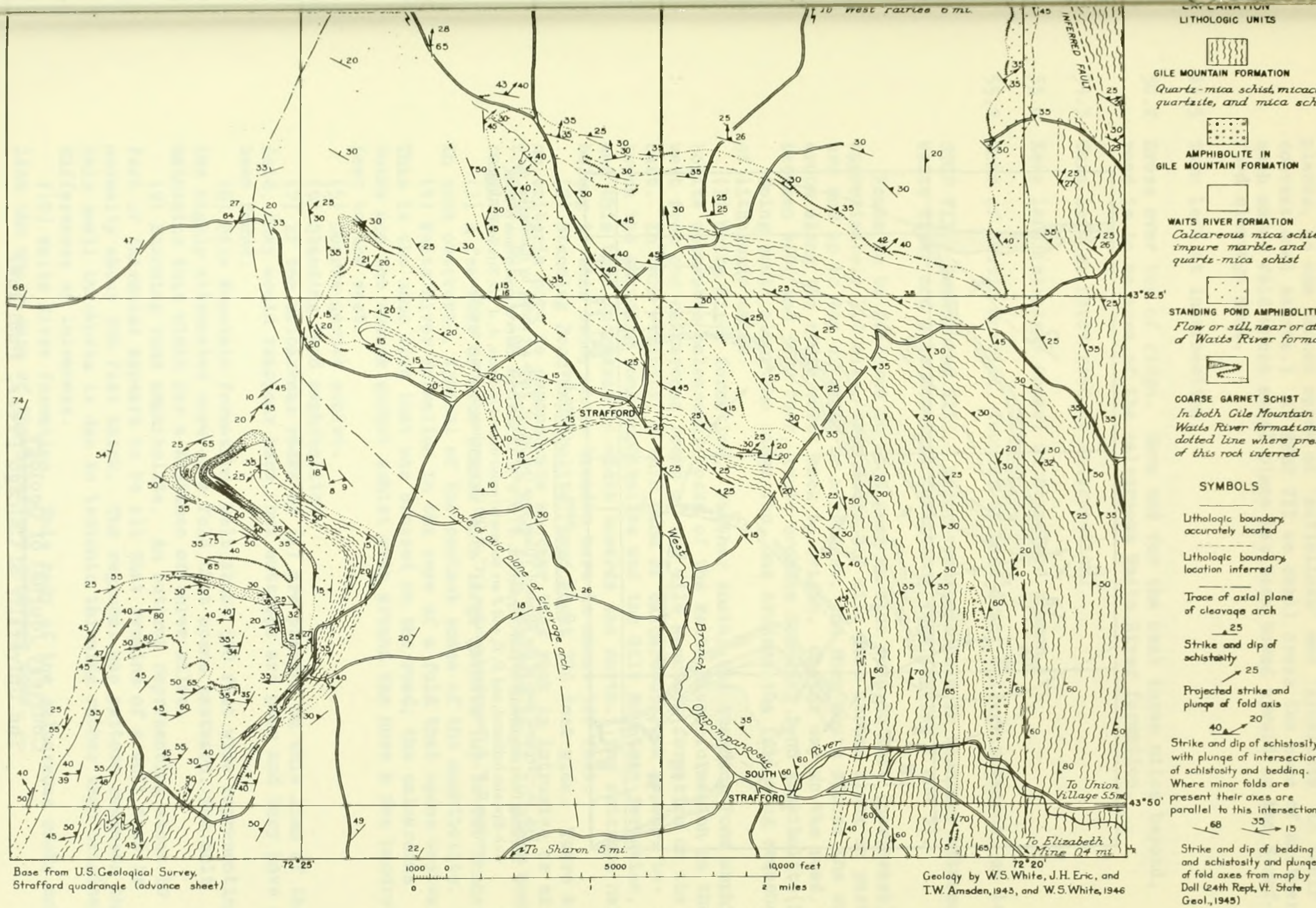


FIG. 9.—Geologic map of the Strafford Village area, Vermont

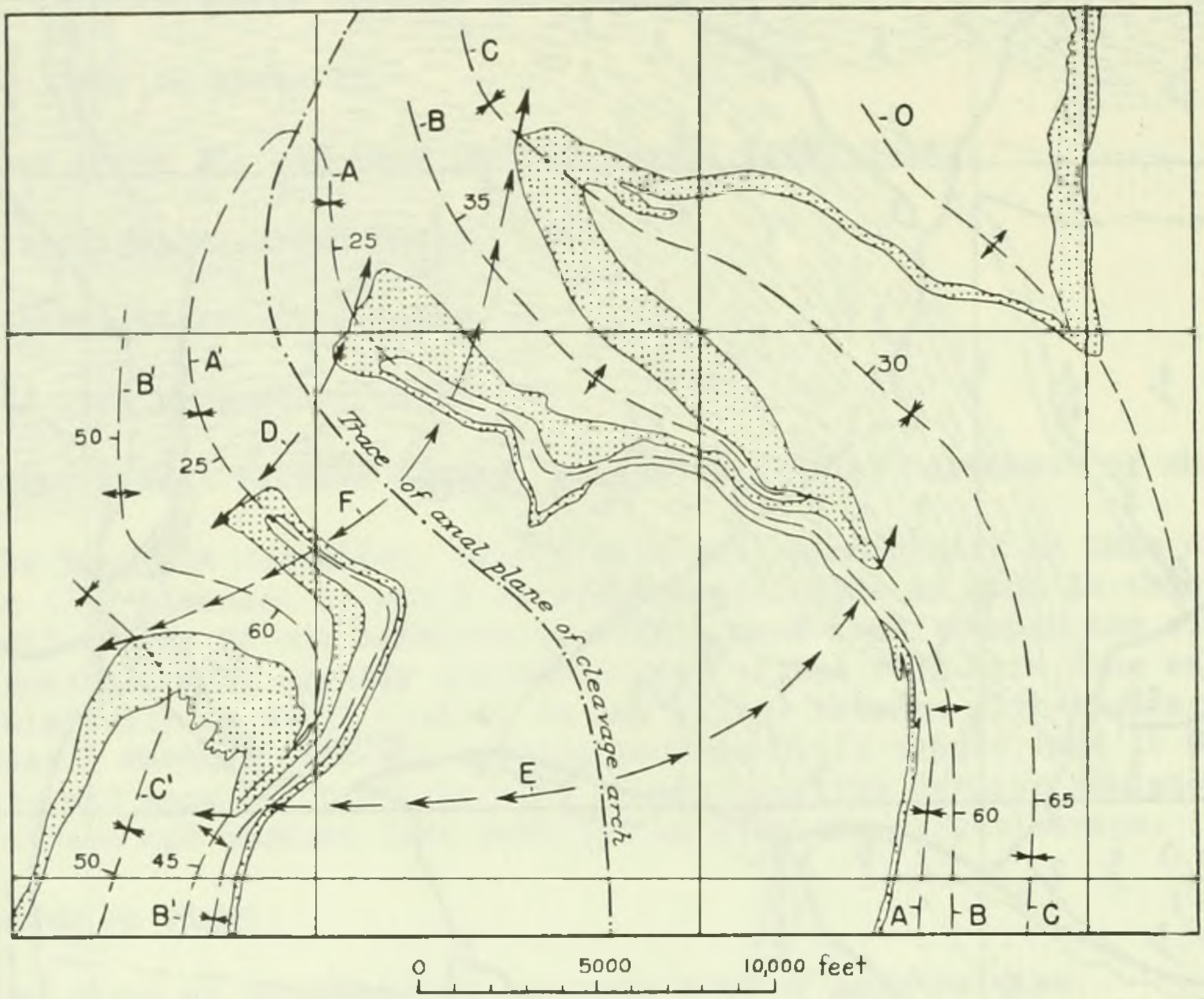


FIG. 10.—Tectonic map of the Strafford Village area (see fig. 9). Folds are shown by distribution of Standing Pond amphibolite of Doll (*stippled*). *A*, *A'*, *B*, *B'*, *C*, *C'*, and *O* are traces of axial planes of folds, with dips also indicated; and *D*, *E*, and *F* are horizontal projections of fold axes, *A*, *A'*, *D*, Strafford Village syncline; *B*, *B'*, *E*, Grannyhand anticline; *C*, *C'*, *F*, Old City syncline; *O*, Orange anticline.

(The plunge of the folds is more or less down the dip of their axial planes, so one cannot speak of "anticlines" and "synclines" in their conventional senses.) At STOP VII we shall cross the core of another such major fold whose axial plane has been bowed upward in the Strafford cleavage dome.

49.5 Turn left at intersection.

50.2 Cross over top of ridge. Here and for the next three miles beyond, road is in an area of the calcareous Waits River formation.

54.3 Turn left on paved road at intersection.

55.0 Keep left (straight ahead) at Strafford common.

55.2 Home of Justin Morrill, founder of Land-Grant College movement, on left.

STOP VII - Grannyhand Hill. Major recumbent fold in boundary between Waits River and Gile Mountain formations (See figures 2 and 3).

Route to be followed on foot goes up side road to left (northeast) approximately 1.0 mile, then about 0.3 mile down across brook in pasture and up to top of ridge to northwest, and then south across the outcrops along the ridge crest back to origin. On the way up the road, between 4000 and 5000 feet, route crosses Standing Pond amphibolite(Dws).

Going south along the ridge top, one crosses the following sequence of lithologic units.

(1) Waits River formation. Farther south, the Standing Pond amphibolite separates calcareous rocks of the Waits River formation on the west from non-calcareous rocks of the Gile Mountain formation on the east. In this vicinity, a thin band of calcareous rock appears between the Standing Pond amphibolite and the Gile Mountain formation, and this band increases in width towards the north. The outcrops here belong to this band, whose breadth here is about 500 feet.

(2) Standing Pond amphibolite, band about 700 feet wide. There are no criteria here to demonstrate whether this rock is intrusive or extrusive, but pillow structures have been observed in it in other quadrangles.

(3) A few feet of mica schist with large garnets (up to two inches in some outcrops), typical of the contact zones of the amphibolite.

(4) Waits River formation in the core of a fold that opens westward. This is the same fold that was crossed on the road; the calcareous rocks and the coarse garnet schist wrap around the nose a few hundred feet to the east.

(5) Coarse-garnet schist.

(6) Standing Pond amphibolite.

(7) If the calcareous rocks of (1) are present on this limb of the fold, they would reappear here, but outcrops are poor and they have not been found.

(8) Gile Mountain formation. Belt about 500 feet wide representing the highly attenuated core of a fold that opens eastward. The belt maintains this width for a distance of three miles.

(9) Standing Pond amphibolite. An outcrop representing about 10 feet of thickness appears to be all that remains of a unit that is normally about 300 feet thick. The regional map pattern suggests that this small thickness is due to tectonic thinning rather than original differences of thickness.

(10) Waits River formation. This body of the calcareous rocks underlies the whole core of the Strafford cleavage dome.

58.7 Turn left, following main road at fork in road at far end of South Strafford village.

61.5 Keep straight on main road at Campbell Corner

63.0 STOP VIII - Rices Mills

Gile Mountain formation, with later folds plunging gently to both north and south.

Large outcrops along both sides of stream to right (southwest) of road. The average attitude of the fold axes is nearly horizontal, as it is in the central part of the Strafford cleavage dome due west of here. The dominant, but not sole pattern of the minor folds suggests relative rise of the rocks on the east with respect to those on the west. This is the characteristic pattern of the later folds on the east side of the cleavage arch.

69.4 Junction of Strafford road with U.S. Rte. 5 at Pompanoosuc.